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Results of Applying the Information Gathering Capabilities of Acceleration and Velocity Signal Processing to HF Radar

[Unclassified Title]

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July 21, 1967

NAVAL RESEARCH LABORATORY
Washington, D.C.

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ABSTRACT
(Secret)

An acceleration and velocity processor is capable of acceleration and velocity matching target signals over a multisecond integration period. Real time operation is achievable with full processing capability for missile as well as aircraft-type targets.

Results are shown for two Polaris missiles launched down the Eastern Test Range and an Athena launched from Green River, Utah. Velocity vs time records of the launch phase are shown where the velocity resolution is 0.36 cps and the signal processing gain is about 26.5 db. Targets appear as discrete narrow tracks many seconds long. Tracks of burning stages, spent stages, and nose fairings are shown. Diffuse exhaust targets may also be recorded if desired and an example is shown.

Acceleration and range data are also available but only range vs time is shown.

The matched spectral bandwidth and amplitude behavior of these targets have also been determined. Frequency analyses of selected targets are shown which reveal the bandwidths and amplitude of these signals. Amplitude vs time records are also shown.

PROBLEM STATUS

This is an interim report on the problem. Work on other phases of the problem is continuing.

AUTHORIZATION

USAF MIPR (30-602) 64-3412 to the
Naval Research Laboratory,
dated 26 March 1964
NRL Problem 53R02-42

RESULTS OF APPLYING THE INFORMATION GATHERING CAPABILITIES OF ACCELERATION AND VELOCITY SIGNAL PROCESSING TO HF RADAR
(Unclassified Title)

INTRODUCTION

The acceleration and velocity processing work at NRL has had the goal of developing an HF radar that would produce a maximum of target information in real time yet remain within the bounds of acceptable system complexity. Such a radar would have high sensitivity derived from appreciable signal processing gain and the highest transmitter and antenna gain that cost and technology would permit.

Signal processing gain is realized by integrating signals over a several second time period. With proper matching in acceleration and velocity over this time period it is possible to realize over 30 db of processing gain and also possible to realize up to 0.1 cps of velocity resolution and 0.1 cps^2 of acceleration resolution for missile as well as aircraft targets. The addition of the acceleration parameter allows an immediate separation of missile and aircraft targets which may be placed on separate displays. This, of course, reduces the number of targets appearing on any one display. Acceleration matching also can discriminate against most meteor effects leaving the displays relatively free of such signals.

These capabilities and a realizable and significant signal processing gain for missiles as well as aircraft have permitted detection of missiles and even the discarded hardware associated with the missile launch. When a time history is made of such targets they form discrete tracks of various lengths. Taken together these tracks form signatures characteristic of specific missiles and thus can aid in identifying and characterizing missile targets.

Acceleration, velocity, and range data may be read directly from the missile signal track itself. The resolution of the acceleration and velocity data is relatively high as previously mentioned.

Further information is available from the system in the form of spectral bandwidth and amplitude data of any of the missile or aircraft signals. These data are probably of more interest to the researcher than to operational personnel who are concerned with positional information. They can provide clues to the useful length of integration time, the maximum realizable velocity and acceleration resolution, propagation path characteristics, and target characteristics.

An effective radar must also minimize the masking and undesirable effects of clutter and interference on the data gathering capability of the radar. NRL's present acceleration and velocity processor controls clutter with a comb filter. In the future, it is proposed that clutter be controlled with wide dynamic range processing circuits. As for interference, the acceleration and velocity signal processing system has a number of features and characteristics which minimize interference.

NRL's work in this area has followed two paths. One is the development of acceleration and velocity analyzing systems and the proof of the principles involved. The second is the use of the resulting systems as improved research tools to further the knowledge of target and propagation path characteristics at high frequencies.

RESULTS

The following data were obtained with the acceleration and velocity processor and the MADRE transmitter and receiver system. The antenna one-way gain was about 18 db including the reflected energy from the ground.

A. ETR 2949

Figure 1 shows the radial velocity vs time data obtained from a Polaris A2 Test 2949, launched on the Eastern Test Range (ETR). Velocity data are shown for targets in a group of acceleration bins that excludes zero and low acceleration bins in order to exclude aircraft targets from the display. Although acceleration as well as range is suppressed on this display, these parameters may be presented on other displays. In this case, targets from a range extent of 500 to 900 naut. mi. may be processed and displayed.

The upper photograph of Fig. 1 shows the results of processing for accelerating targets while the lower photograph is for decelerating targets. The velocity extent becomes ambiguous at about 900 knots which causes target tracks to fold at this value. The operating frequency was 15.595 Mc/s and the PRF 90 pps.

Three of the four tracks on this figure are particularly narrow and well defined and persist for about 1/3 minute. This indicates that integration times up to 20 seconds are useful.

These data have been replotted on Figure 2 for a comparison with a calculated radial velocity-time history based on ETR postflight data. The computed velocity drops to zero at 135 seconds because this is the time at which the ray path and the missile trajectory intersect at 90 degrees. The two paired tracks agree closely with the computed curve and one is presumed to be the burning second stage and the other related to the reentry body separation. The signal appearing at 145 seconds is believed to be the spent first stage.

Other data are also available from the acceleration and velocity processor. Figure 3 shows range vs time and amplitude vs time data on the three targets appearing in the deceleration analysis. The range of the second stage is seen to differ from that of the spent first stage as expected. The variation of amplitude with time is clearly indicated for the two groups of signals.

A frequency analysis was made of each of the three deceleration signals to obtain a measure of their matched spectral bandwidth as shown on Fig. 4. The velocity resolution of the acceleration and velocity processor was about 1/3 cps. When a stable calibration signal with a bandwidth less than 0.1 cps wide is analyzed in steps of 0.12 cps the result is as shown in the upper right-hand view. The amplitude vs frequency characteristic of the analyzing filter is outlined. However, it is possible to state that the bandwidth of the calibration signal is equal to or less than 1/3 cps from this evidence. One other factor should be mentioned here and that is that the matching process is not perfect and may broaden the target signal as much as 0.1 cps. Therefore this value should be subtracted from the above-indicated target bandwidth.

The other three records of this figure are frequency analyses of the three decelerating targets. The upper and middle photographic records correspond to the upper and lower paired signals and the lower record corresponds to the third target signal. These records indicate that the individual target bandwidths are on the order of 1/3 cps or slightly wider.

It should also be noted that a precise amplitude may be read for each of the separate targets. Here the amplitude of the burning second stage is seen to be very little greater than that of the spent first stage.

B. WSMR 021-C005-B06

An observation was made of the early launch phase of Athena 021 which was launched from Green River, Utah on the White Sands Missile Range (WSMR). An operating frequency of 13.661 Mc/s was used along with a PRF of 45 pps. Figure 5 shows the results of both acceleration and deceleration analyses.

Many discrete target tracks appear on the two records. It is believed that a track of the burning second stage is shown, that somewhat broader returns of the second stage exhaust appear separately, and that narrow tracks of the spent first stage, spent second stage and coasting third and fourth stages also are shown.

Range and amplitude data are shown on Fig. 6 for several of the accelerating targets. As indicated, the radar range to these targets is about 1600 naut. mi. The signal amplitude of the two targets is seen to be comparable.

A frequency analysis was made of a number of the separate Athena target tracks which are shown on Fig. 7. The three left-hand records are acceleration analyses of the burning second-stage track taken a few seconds apart. They indicate a spectral bandwidth of less than 1/3 cps and a signal amplitude on the order of 1.0 μV.

A frequency analysis was also made of a second-stage exhaust track and a coasting-stage track from the deceleration analysis and the results are shown on Fig. 7 in the upper and middle right-hand position, respectively. The bandwidth of the exhaust signal is about 1/3 cps. However, the signal as a whole is surrounded by a higher level diffuse energy. The coasting stage has a more distinct return and a reduced bandwidth with less diffuse energy in the background.

C. ETR 3058

A Polaris A3 missile launched on the ETR was observed with an operating frequency of 13.680 Mc/s and a PRF of 90 pps. One acceleration analysis and three separate deceleration analyses were made and are shown on Fig. 8. The three deceleration analyses are repeats of the same event made by rerunning a taped record of the event. The purpose was to first present the diffuse signal return from this event, as shown in the upper right-hand record, and then to emphasize the discrete signals, as has been accomplished in two steps in the middle and lower right-hand records. This is one of the flexibilities of the acceleration and velocity processor.

It has produced an interesting result here. The 3058 Polaris is reported to have malfunctioned and blown up at 126 seconds. The diffuse record seems to clearly confirm this report.

The discrete record is believed to show tracks of the nose fairing, burning second stage, and spent first stage.

Again, range-time and amplitude-time records are shown on Fig. 9. The various pieces of the missile are at different ranges as indicated here. The amplitude of the various targets is seen to be fairly comparable.

Figure 10 shows the frequency analysis records of this missile. The three left-hand records were made a few seconds apart on the decelerating second-stage target. The spectral bandwidth of this target is no more than 1/3 cps although the record has been obscured, in two cases, by an interference. The lower right-hand record is from an acceleration analysis at about 76 seconds and shows the target track to have a bandwidth comparable to 1/3 cps. The amplitude of these separate targets is seen to be on the order of 10 μV.

CONCLUSIONS

Acceleration and velocity matching of targets with spectral bandwidths equal to or less than 1/3 cps has been accomplished. This results in good velocity and acceleration resolution of missile and aircraft targets. Similarly, processing gains of up to 30 db are realizable for these targets due to the feasibility of 10- and 20-second integration times with matched operation.

Many missile targets have been found to have matched bandwidths equal to or less than 1/3 cps.

The acceleration parameter permits separation of missile and aircraft targets which may be presented on separate displays. This results in displays having fewer distracting signals and less clutter.

Various pieces of missile hardware, such as burning stages, spent stages, nose fairings, and coasting stages are detectable and appear as discrete tracks with good resolution. All of these capabilities will facilitate target detection and characterization.

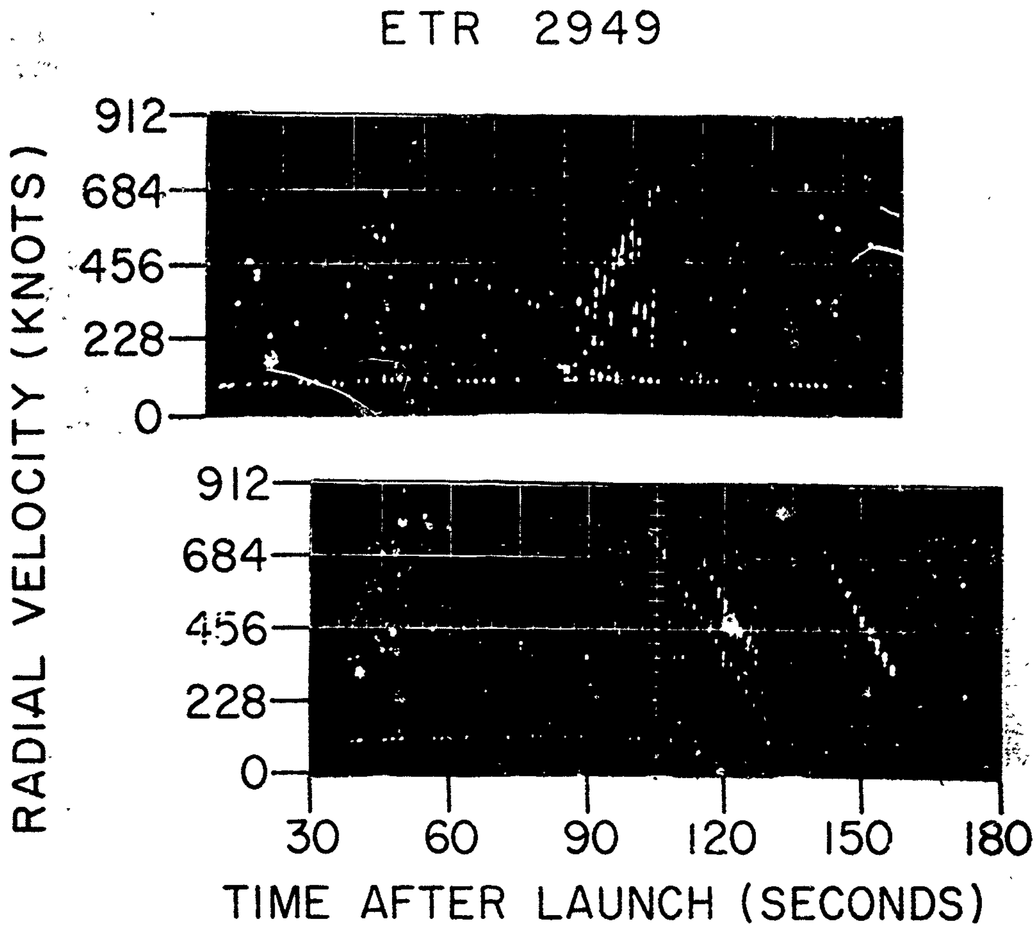

Fig. 1 - Velocity-time profile of ETR Test 2949 (A2 Polaris launch). The lower profile is for decelerating targets and the upper profile is for accelerating targets.

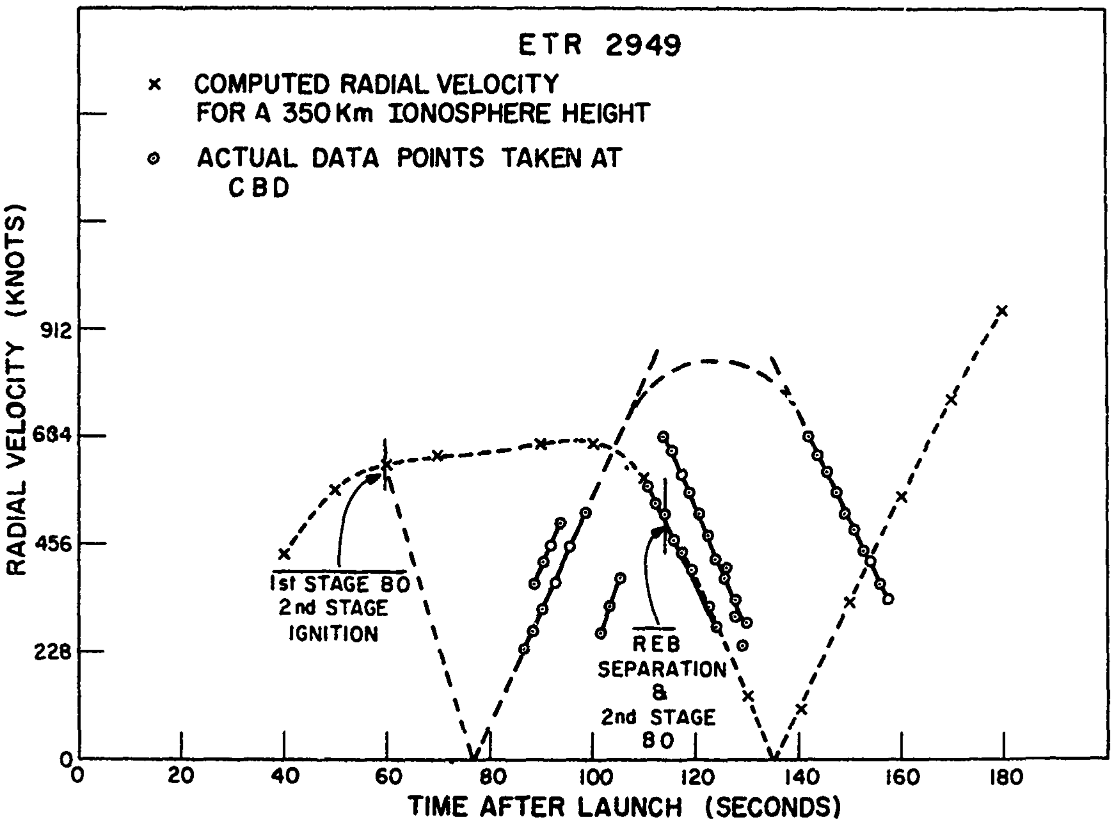

Fig. 2 - Calculated velocity-time profile of ETR Test 2949 from ETR postflight information as compared with actual radar data points transcribed from Fig. 1.

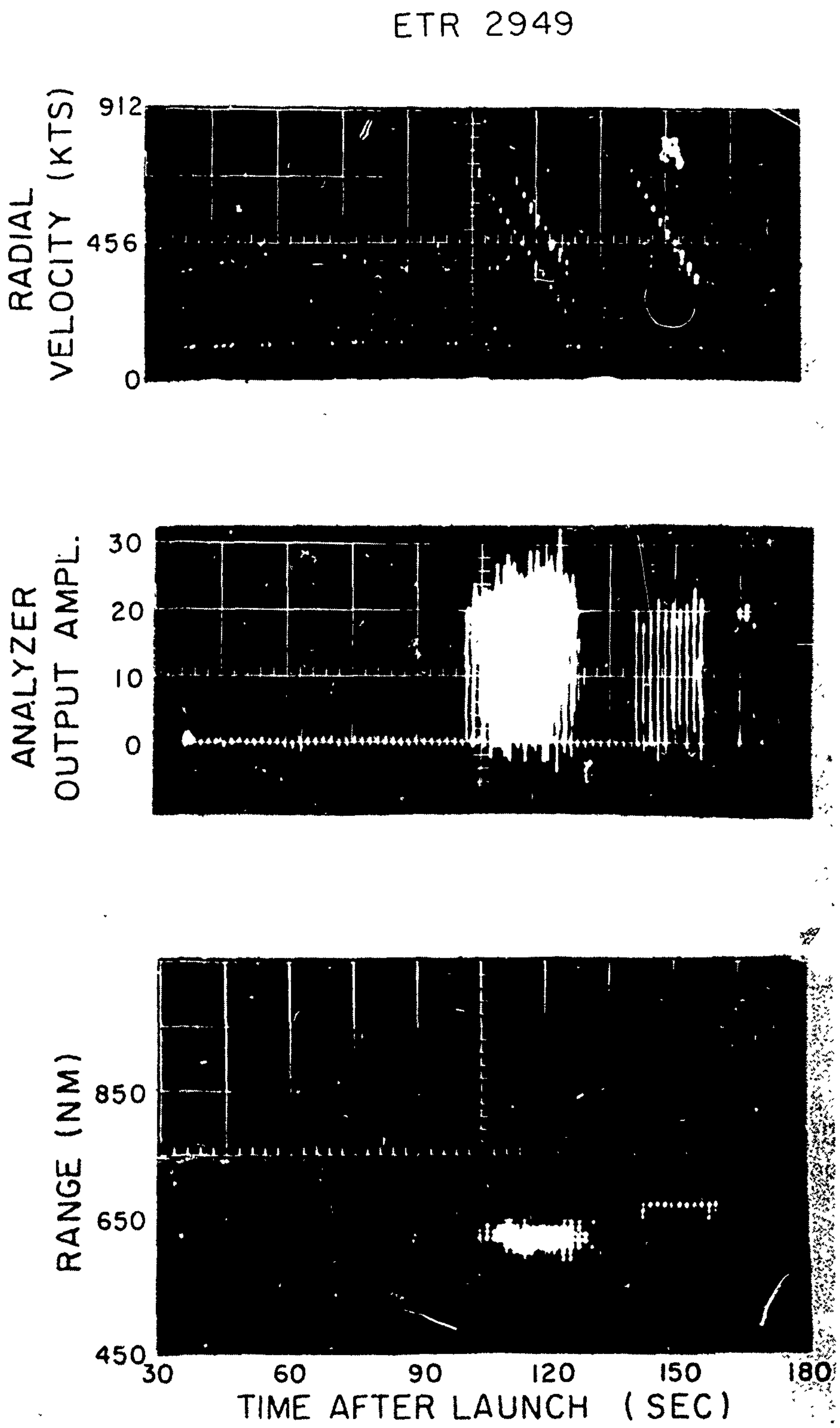

Fig. 3 - Range-time and amplitude-time data of ETR 2949

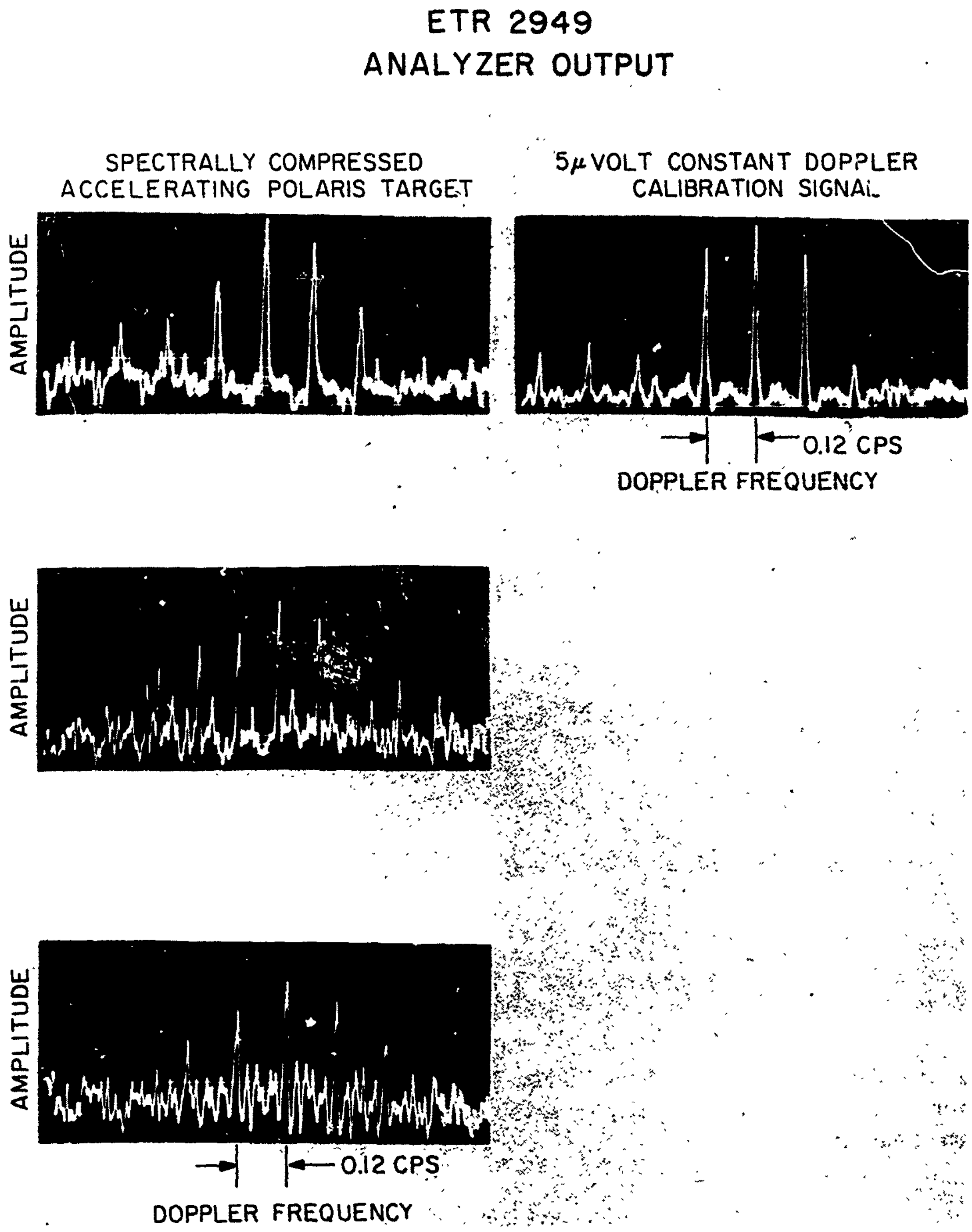

Fig. 4 - Doppler frequency analysis of ETR 2949. Three target analyses are compared with that of a stable calibration signal having a bandwidth of less than 0.1 cps. The top-to-bottom order of target analysis corresponds to a 2, 1, 3 left-to-right order of the targets shown in the decelerating profile of Fig. 1.

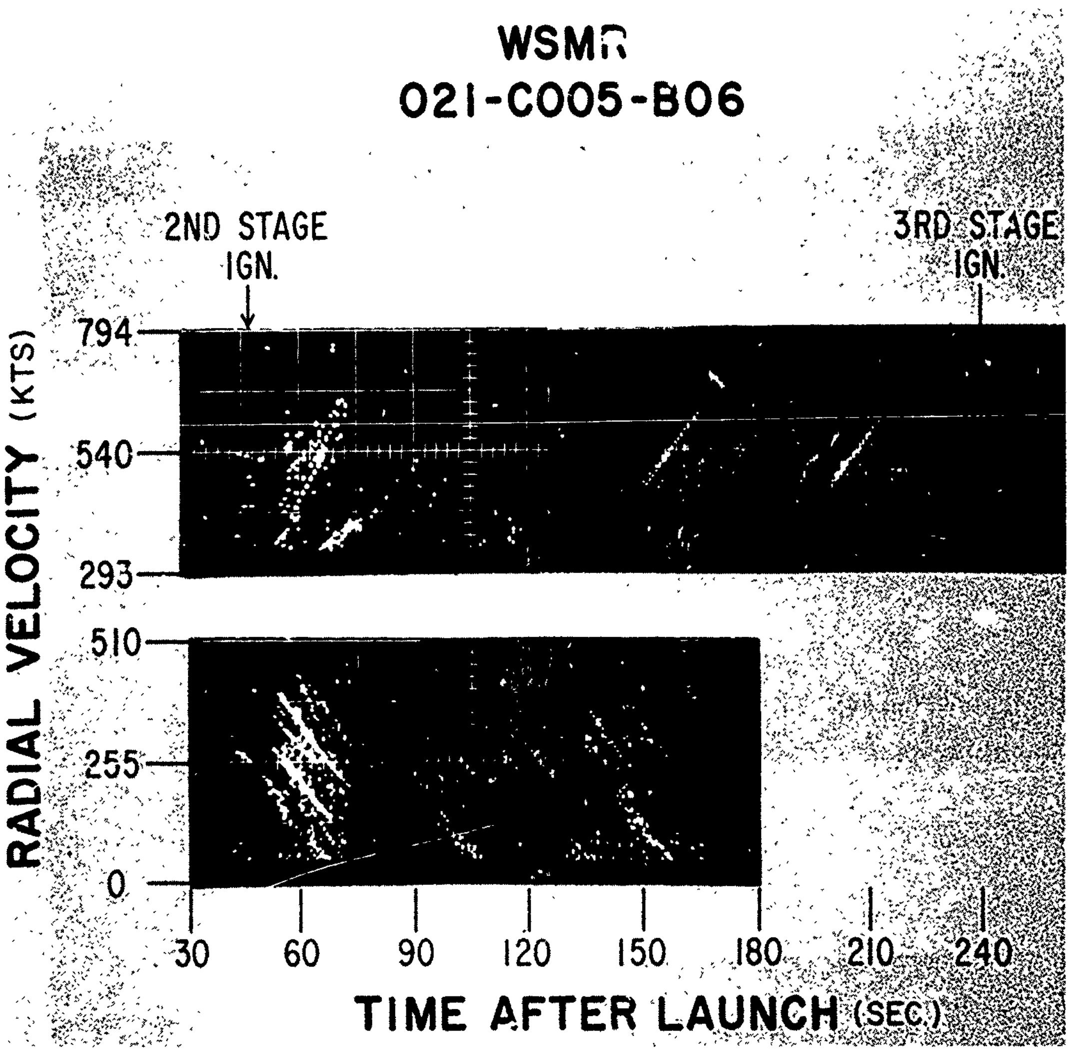

Fig. 5 - Velocity-time profile of WSMR Test 021-C005-B06 (Athena). The lower profile is for decelerating targets and the upper profile is for accelerating targets.

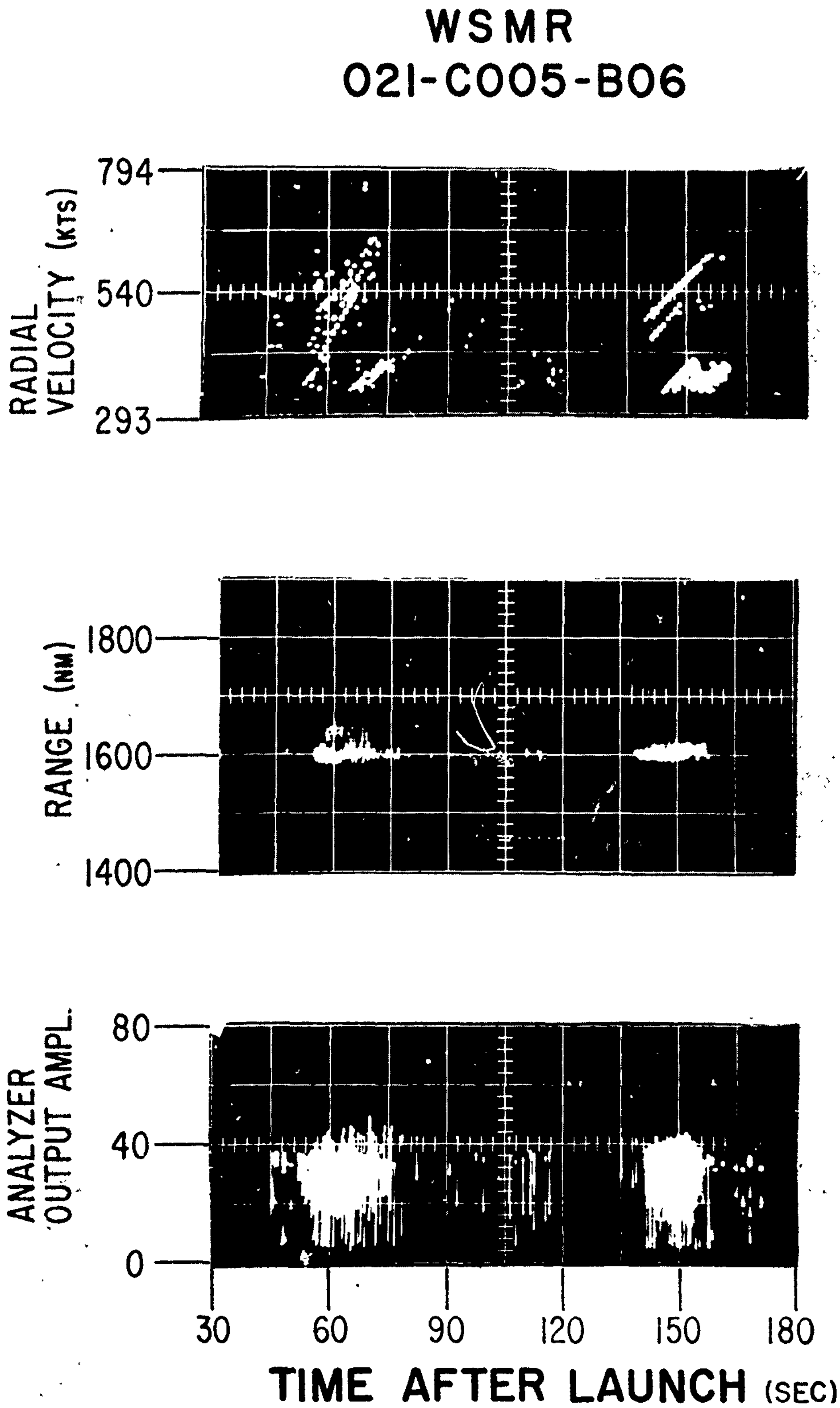

Fig. 6 - Range-time and amplitude-time data of WSMR Test 021-C005-B06

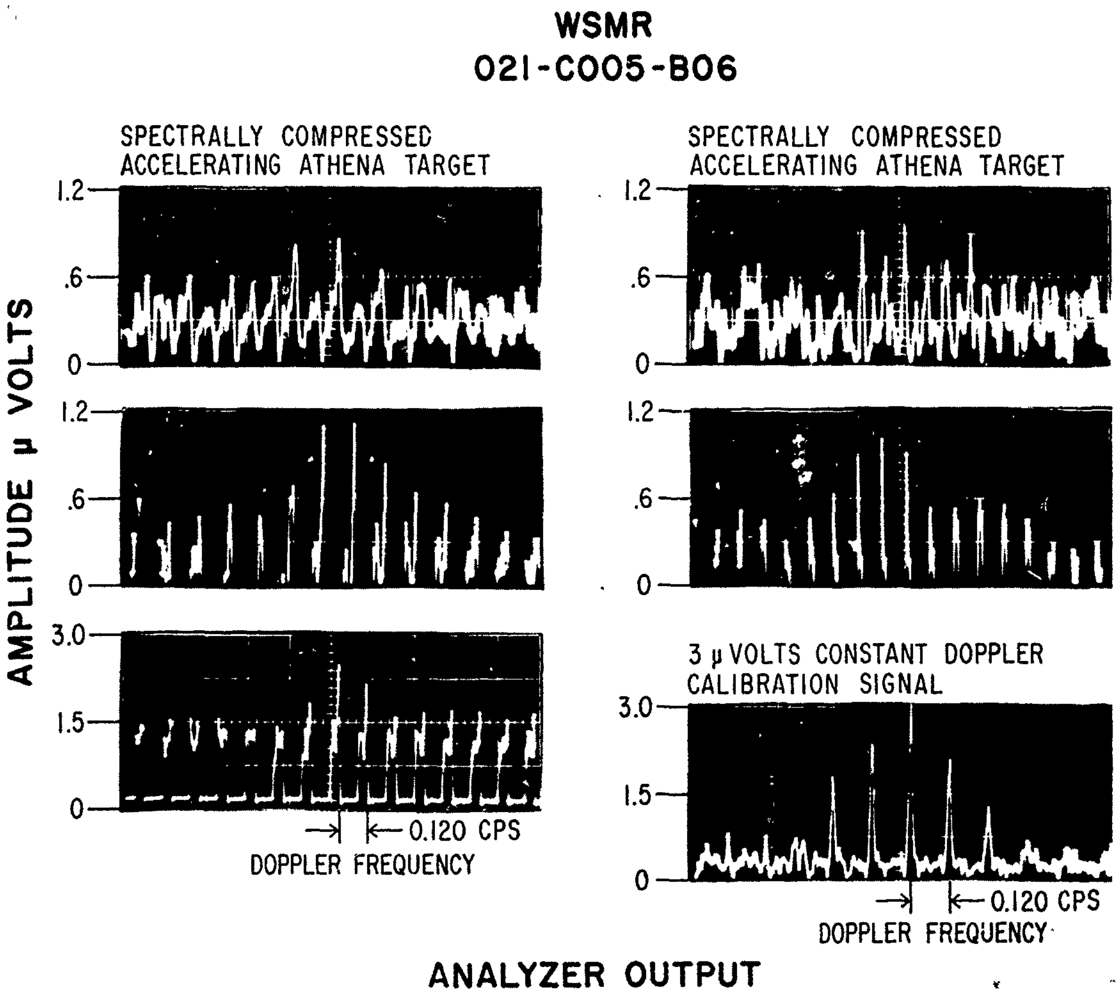

Fig. 7 - Doppler frequency analysis of WSMR Test 021-C005-B06. Five target analyses are compared with a stable calibration signal having a bandwidth of less than 0.1 cps. The three left-hand records are acceleration analyses of the burning second-stage track taken a few seconds apart. The upper and middle right-hand records are decelerating analyses of a second-stage exhaust track at 57 seconds and a coasting-stage track at 125 seconds, respectively.

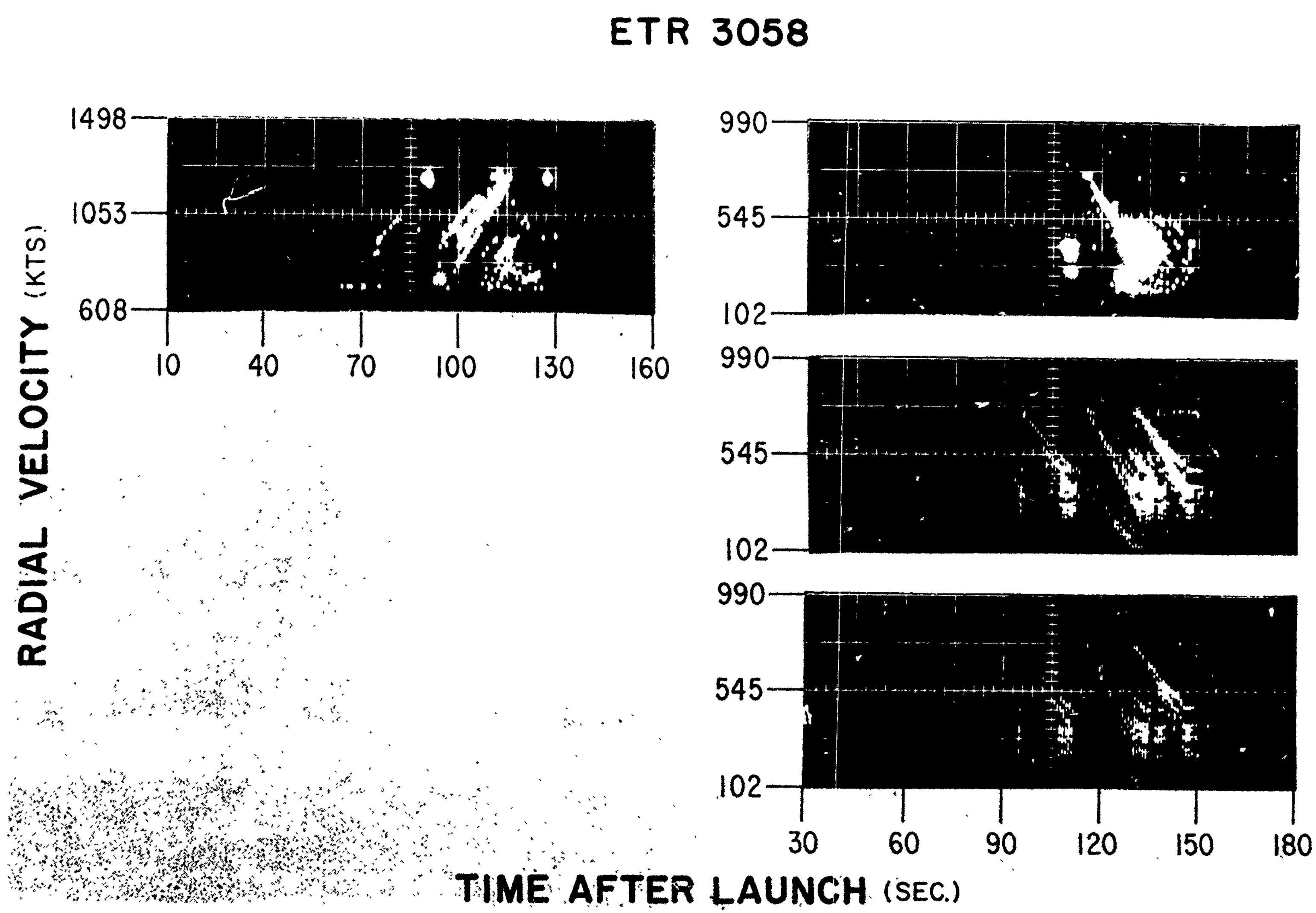

Fig. 8 - Velocity-time profile of ETR 3058 (A3 Polaris). The left-hand profile is for accelerating targets and the right-hand profile is for decelerating targets. (The analysis has been repeated three times first emphasizing diffuse signals and next discrete signals.)

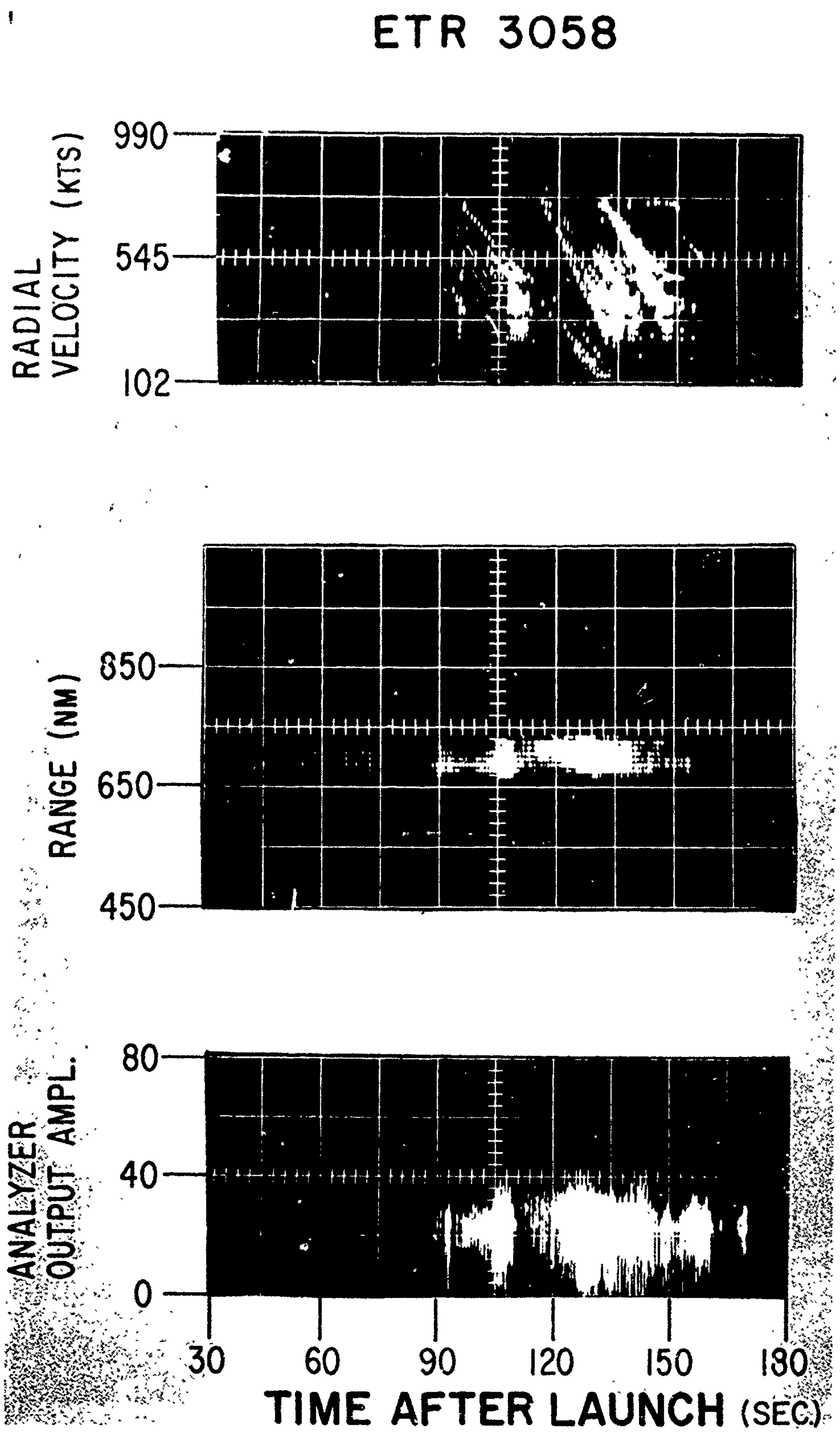

Fig. 9 - Range-time and amplitude-time data for ETR 3058

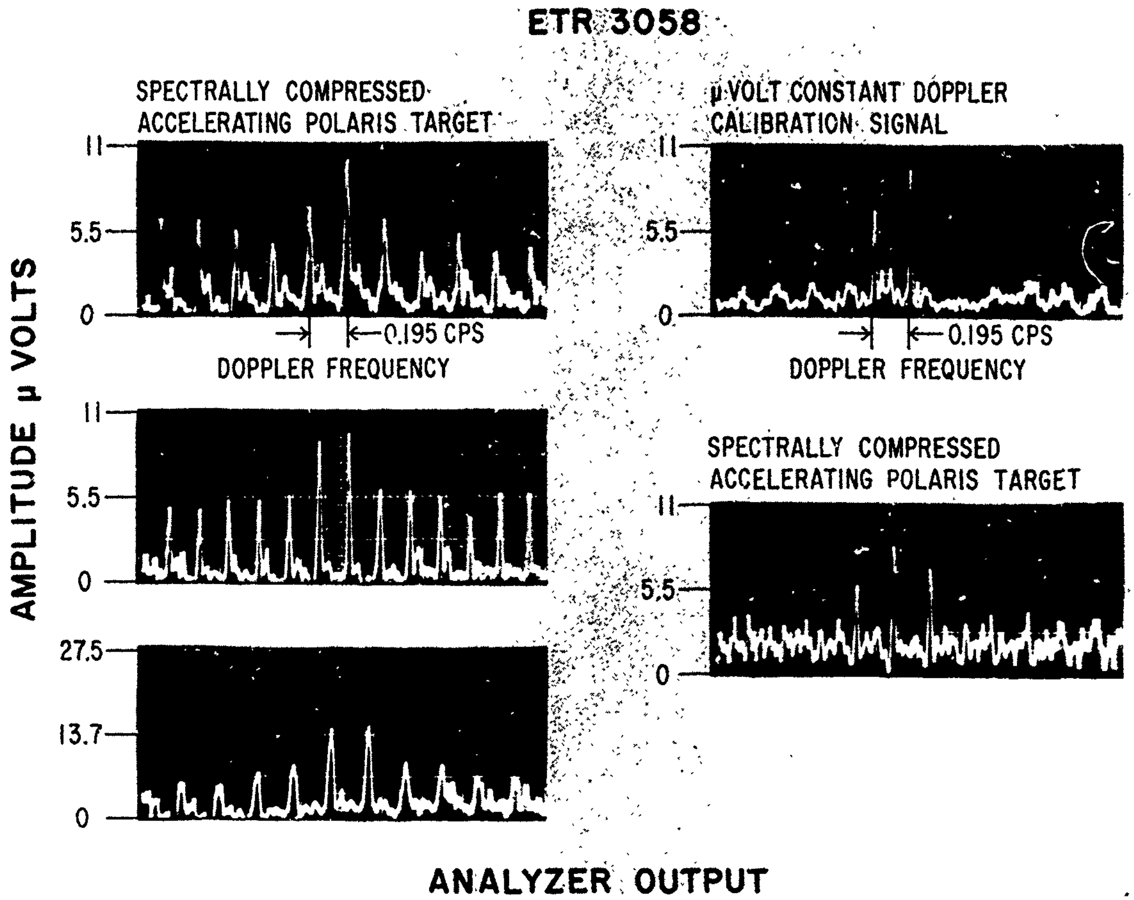

Fig. 10 - Doppler frequency analysis of ETR 3058. Four target analyses are compared with a stable calibration signal having a bandwidth less than 0.1 cps. The three left-hand records top to bottom are deceleration analyses of the burning second stage (two are five seconds apart around 110 seconds) and the spent first stage at 130 seconds, respectively. The right-hand record is an acceleration analysis of the track at about 76 seconds.

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13 ABSTRACT (Secret)

An acceleration and velocity processor is capable of acceleration and velocity matching target signals over a multisecond integration period. Real time operation is achievable with full processing capability for missile as well as aircraft-type targets.

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MEMORANDUM

20 February 1997

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